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GREENLAND WEST-COAST FOEHNS: A DISCUSSION BASED ON THE FOEHNS OF JANUARY, 1929

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At the University of Michigan aerological station, Mount Evans, situated 75 miles east of Davis Strait, 30 miles west of the margin of the Greenland ice-cap, and 1,292 feet above sea level in latitude 66° 55′ N., and longitude 50° 50′ W., it is remarkable that one-fourth of the days of January, 1929, had hourly temperature averages above freezing. Also, during the same month along the west Greenland coast there was a new maximum temperature 10° higher than any January maximum temperature of the past 30 years.

In this paper these relatively high temperatures and periods of warm weather together with the other outstanding features associated with the three January foehns are set forth in the order in which the foehns occurred; also the exact nature and extent of the temperature, pressure, cloud, and wind changes occurring throughout the greater part of the month at one place in this west-coast region are shown by the graphs of the Mount Evans data. (Fig. 1.) But in this paper these weather summaries are included mainly because they serve as the fact basis for the chief consideration of this discussion, which is to show that the place of origin, manner of growth, and track of the LOW, are factors which largely determine the strength of the foehn. In this discussion, too, a new significance is attached to the Labrador northward moving secondary, a pressure development which has long been observed but never clearly analyzed.

Throughout the following pages Mount Evans data, Norwegian and Deutsche Seewarte synoptic charts and weather records kindly supplied by the Danish Meteorological Office have been the writer's chief references. Also at this place, the writer wishes to express his acknowledgments to Prof. H. U. Sverdrup and Dr. J. Bjerknes for their valuable counsel, and to Prof. W. H. Hobbs for permission to use the Mount Evans data.

We shall begin by pointing out the pressure distribution which was associated with the foehn of the 8th.

THE FOEHN—JANUARY 8, 1929

The pressure distribution during the first foehn was characterized by a remarkably high pressure to the east and south and a very low pressure to the west of Greenland. Let us consider each of these pressure developments for a moment. The beginning of the great high-pressure area may be said to have been on the 6th of January, when an already extensive European HIGH[1] joined the north Greenland anticyclone. The next important step occurred on the 7th when this newly combined HIGH joined a subtropic HIGH through the region 25° W. and 45° N., and when this occurred a great high-pressure ridge was set up, a ridge which extended across the North Atlantic from eastern and northern Greenland southward to the horse latitudes. This was the HIGH's maximum extent, but the development of the low-pressure area was perhaps more outstanding.

The LOW entered the United States over the State of Washington on the 2d of January and on the 5th we find it near Kansas City, Mo. However, it was after the LOW moved away from this plains region that it developed in a most singular manner. In fact, in the 24-hour movement from Kansas City the LOW not only became deeper by 0.52 inch, but it moved northeastward at an astonishing rate covering nearly 1,000 miles.[2] Following this, instead of continuing eastward and entering over the Atlantic Ocean we find that the above-mentioned vast Atlantic HIGH turned the LOW northward. At 10 p. m.[3] on the 7th, therefore, the LOW was centered near Cape Chidley as an exceptionally deep depression of the order of 27.91 inches. Twenty-four hours later, following a northeasterly course across Davis Strait, the LOW became occluded in the Jacobshavn-Upernivik district, but of concern here is that with the occlusion was the occurrence of the foehn, the features of which are as follows:

At Mount Evans, which was near the center of this LOW during its occlusion, anticyclonic weather preceded the foehn. Shortly before the foehn outbreak, however, which occurred about midnight of the 7th and which was marked by a temperature rise from 2° to 27°, three outstanding weather changes should be noted. In the order of their occurrence they were: (1) 6 a. m., beginning of the pressure decrease, (2) 10 a. m., gradually increasing sky cover of cirro-stratus from the south, and (3) 4 p. m., a beginning of slowly rising temperature. In the upper air, at least 12 hours before the outbreak, air was moving from off the ice-cap between the surface and 2,500 m. at a rather uniform velocity of approximately 7 m. p. s. (See fig. 4.) Above this, between 3,500 m. and at least to 5,000 m. and increasing with height from 11 to 27 m. p. s., air from the southwest was moving into the upper levels of the high-pressure region over the inland ice. It appears reasonably certain then, that air at the lowest levels at the ice margin was being impelled outward by the inflowing air aloft. At any rate, this air at the lowest levels could scarcely have come from the east coast of Greenland, at least at a corresponding level, for Scoresbysund on the 7th, had west wind and a temperature rise of 41.5°.

[1] The terms "High" and "anticyclone" are used synonymously.—Ed.

[2] M. W. R., Jan. 1929.—A. J. Henry—"Notes on January Weather."

[3] Time references are all according to 45th meridian time.

THE FOEHN—JANUARY 12–15, 1929

Down-slope winds of the 12th, 13th, and part of the 14th, which finally brought an extraordinary maximum of 50° to Mount Evans, must be attributed more to the increase in the pressure over the ice-cap region than to a decrease of pressure over Davis Strait. In fact, Angmagssalik, Scoresbysund, Upernivik, and Mount Evans had their highest pressures of the first half of the month at this time, and after the 10th readings lower than 29.33 inches did not occur in the immediate vicinity of Davis Strait until late on the 15th, when Cape Chidley reported 28.74 inches.

The singular beginning again of the foehn on the 15th, after an approximate 24-hour interruption in which there was an outbreak of cold air from the north, was apparently due to the increased pressure gradient brought about by a newly-formed and deeper depression lying centered over northern Hudson Bay. On the 16th temperature and pressure had already begun to decrease, but on this day four quick pressure decreases followed by equal increases were outstanding. These fluctuations are, no doubt, to be ascribed to outrushes of air taking place when the depression was near enough to release some of the ice-cap air.

Upper-air conditions on the 11th, as on the day preceding the 8th, showed air from the southwest at high levels at approximately 5,000 meters. Whether this current increased or decreased after the 11th can not be stated because clouds in the neighborhood of 2,500 meters cut short the pilot-balloon flights. Below the cloud level wind prevailed from off the ice cap during the days of the foehn.

THE FOEHN—JANUARY 21–25, 1929

The third foehn was the most outstanding; Mount Evans had a high maximum of 51.8° and 102 consecutive hours averaging 10° above freezing, and Godthaab and Jacobshavn had maximums of 61.3° and 59.1°, respectively 9.9° and 10° greater than their next highest January maximums at least since 1900.[4] In addition to these temperatures there were three features which were outstanding at Mount Evans. They were: (1) Fluctuating pressure on and about the 23d; (2) wind of great velocity occurring on the first five hours of the 24th, the hourly velocities in miles per hour being 56, 80, 73, 70, and 52; and (3) the high pressure following the temperature decrease and the end of the foehn. It is interesting to note that these exceptional conditions occurred under pressure conditions which were also peculiar.

The LOW contributing to the development of this foehn may again be traced to the plains region of the United States, and in the 24-hour movement from that region it proceeded in a manner even more unusual than the LOW of the 8th, for after the morning of the 18th, while the LOW became deeper by only 0.36 inch, it moved northeastward an amazing distance, approximately 1,500 miles.[5] Compared with the earlier depression, the distance was farther and the deepening not so great, but in a later stage east of Labrador the pressure (27.75 inches at 10 p. m. January 21) was 0.16 inch lower than the Cape Chidley LOW. High pressure over the eastern North Atlantic Ocean was again, no doubt, a chief factor in stopping the LOW immediately east of Labrador, but increase in pressure along the east and west coast and therefore presumably over Greenland, roughly estimated at a minimum 0.50 inch greater than on the foehn of the 8th, probably partly accounts for the greater development of the foehn of the 21st.

However, too great significance should not be given this increase in pressure, for it may also have tended to decrease the strength of the foehn by reducing the pressure gradient between the coastal region and that over the ice cap. Thus the strength of the foehn becomes not so much a matter of the depth of the pressure along the coast (for as such the first foehn should have reached the highest temperatures), but it is as will be explained, instead, a matter which reverts to the origin and course of the LOW.

In the case of the last foehn it will be repeated that the center of the LOW followed a southerly course and moved eastward over the St. Lawrence track, but a significant fact is that it was extremely deep and that it became a great stationary cyclone east of Labrador. Since this depression remained fairly deep over four or five days and since there is not definite proof that the original LOW moved northward, then the pressure and temperature changes which occurred along the Greenland coast during these days must be attributed to secondaries of this stationary depression. With this being true, if their origin and growth are explained, then certain comparisons can be made between Labrador secondaries and those LOWS which come directly to the Greenland coast after having first crossed North America. The second foehn without any well-formed LOW moving toward Greenland from North America also came about while the Labrador LOW was especially well marked, so the matter of secondaries might again be considered, but since the secondaries of the second and third foehns show so much in common, only one discussion of this type is necessary. Concerning the first foehn and its LOW of a different character, however, all comparisons and explanations will come after the following discussion which considers how secondaries may form on the north or cold side of a stationary Labrador cyclone.

Two contiguous masses of air of unlike temperature moving in opposite directions, or with different velocities in the same direction, are sufficient cause for the formation of a cyclonic depression.[6] Near the Greenland coastal fringe either of these ways may be operative in forming a secondary, but in any case it is the movement of air from off the ice cap which seems to be all important. In other words, it is to be understood that the ice cap as a great topographic feature is of such height, character, and extent that it becomes a dominant control in at least one part of the weather of the Arctic. In a situation like that of the 21st, for example, as is shown in Figure 2, the part played by the ice cap in building the secondary is clearly evident.

As is shown on the figure, a great amount of air moving around the north of the Labrador LOW is deflected around the Cape Farewell region. With this deflection comes an increase in velocity which probably carries much of the air over the southernmost part of the ice mass. Therefore, when it descends from this elevation the air will be warmed adiabatically and a temperature difference between this air and that in Davis Strait will begin. This is the step which is so important at the beginning, for by reason of this increase in temperature and consequent decrease in pressure an increasingly larger amount of air from over the ice cap will descend and be pushed onto the coastal region, will increase the extent and temperature of the warm air there. But all further increases

[4] Data not available for Jacobshavn for the years 1912 and 1918; for Upernivik in 1913, 1914, and 1927.

[5] MONTHLY WEATHER REVIEW, ibid.

[6] According to the Bergen School.

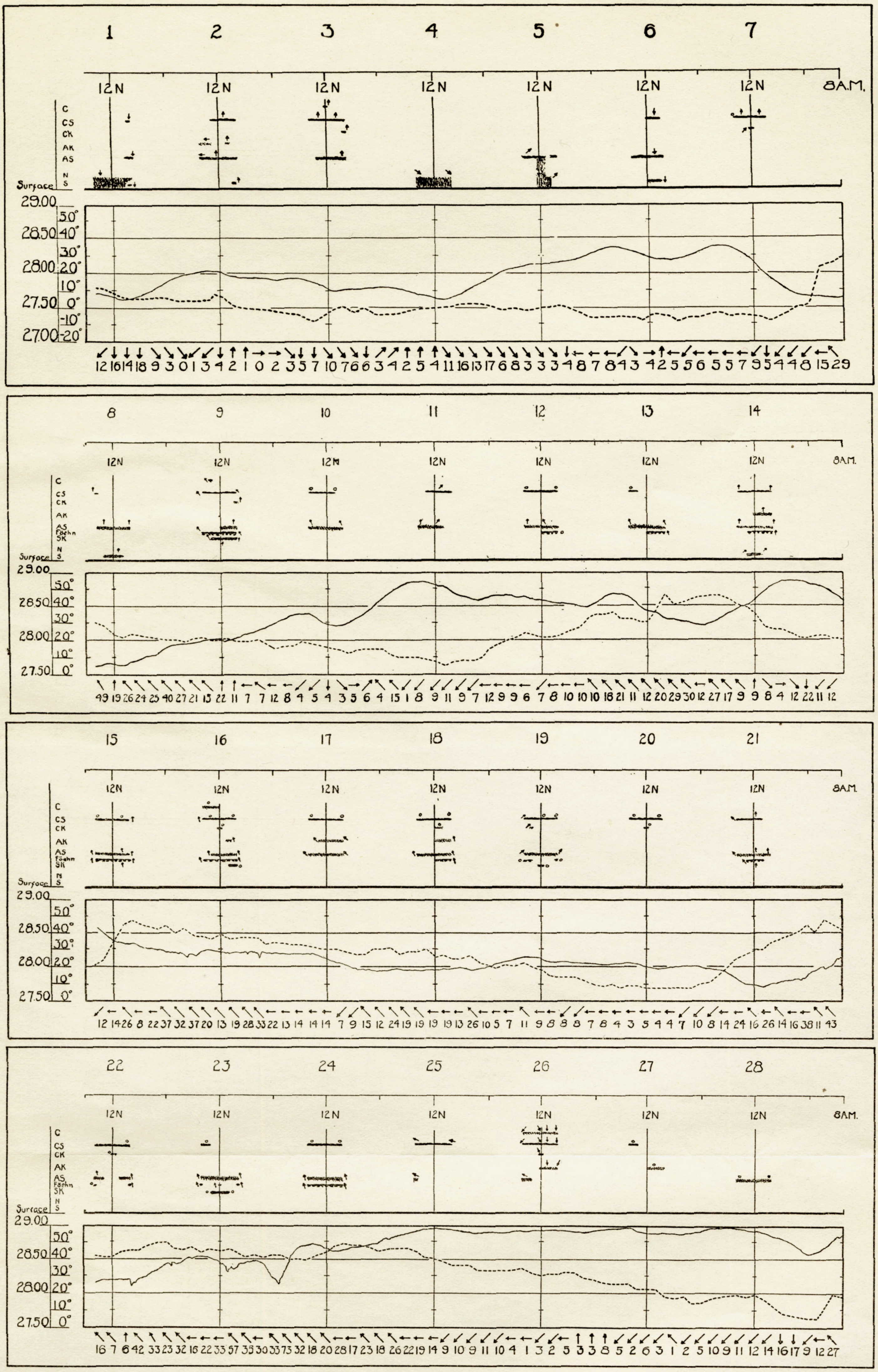

FIGURE 1.—Graphic representation of meteorological data of Mount Evans from Jan. 1 to 28, 1929. Numbers across the top refer to days; "12 N" is 12 o'clock noon. Cloud heights are represented as being alike on all days. Direction of cloud movement is shown by arrows which fly with the wind; the top of the graph is north, the right side, east and so on. The broken line represents the temperatures of every second-hour; the solid line is a reproduction of the barograph trace (add 1.39 for sea-level values). Wind direction and velocity in miles per hour is for every third hour

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will be arrested if there is no provision for retaining the warm air at or near the coastal region. At this stage in the development, therefore, it is essential to have a well-formed pressure trough between the polar air in Davis Strait and the warm air at the coast. This prevents the warm air from being dissipated, but in addition it brings into being a definite surface of discontinuity along which a secondary might develop. It should be noted in passing that Figures 2 and 3 show the surface of discontinuity at the coast where the eastward limit of the north-south prevailing wind of Davis Strait usually

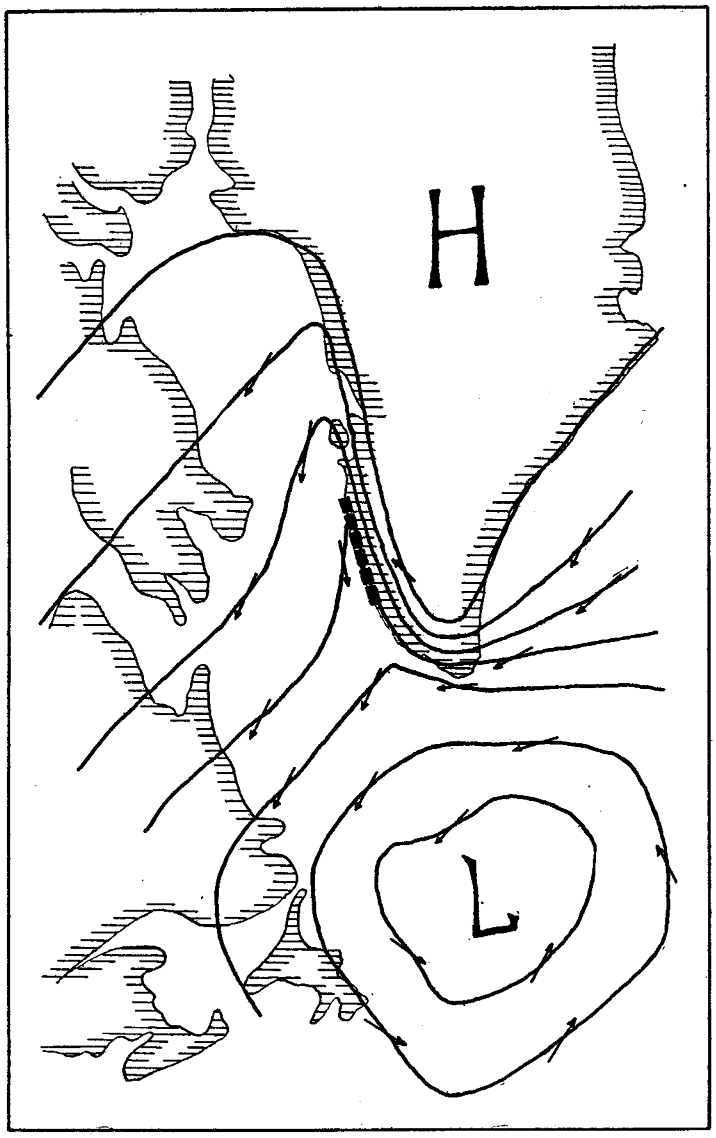

FIGURE 2.—The first step in the formation of a Labrador secondary. Note how the Greenland anticyclone and ice mass extend as a wedge into the Labrador LOW and how the increased wind velocity at southern Greenland is explained by the crowding of isobars in that region. The wide broken line represents a line of discontinuity

occurs. However, the exact place of this surface will largely be determined by such factors as the strength of the foehn or the conditions of pressure or temperature of the polar air in Davis Strait.

With a discontinuity surface definitely formed, the development of the secondary may occur anywhere along its extent. For example, Figure 3, Part I, shows how the outpouring from off the grand slope of the ice cap may provide a large amount of warm air to any wave which might form; in Parts II and III the amplitude of the warm wave is increased, the polar air is pushed aside and some of it is shown here moving toward the north, to the back side of the warm sector. Further increase in the westward extent of the tongue of warm air after stage III allows the polar air to cut off the warm sector from further connection with the down-slope winds; stage IV shows the situation after occlusion has occurred. Two striking examples of a south and a north wind during different stages of the occlusion are represented by the 19th and 6th on Figure 4.

However, whether these depressions are small like those indicated by the pressure fluctuations on the 16th and 23d, or larger ones, at least six factors determine how far northward the newly formed LOWS may go before they

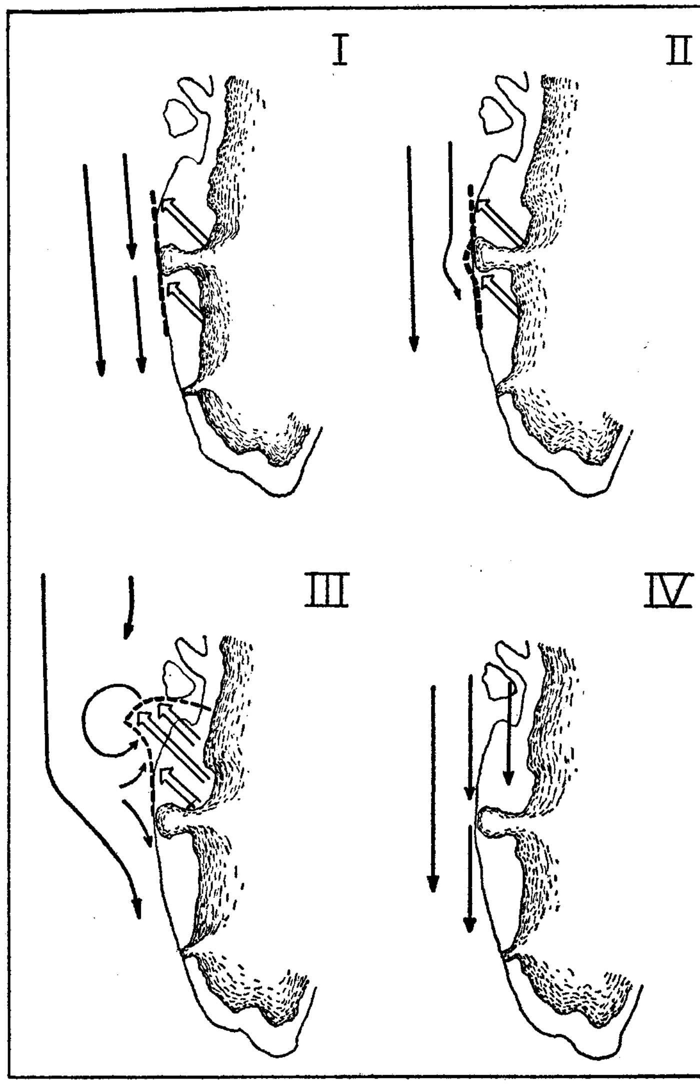

FIGURE 3.—A continuance of the situation begun in Figure 2

are occluded. Listed somewhat according to significance, consideration must always be given to the first five of the following: (1) The energy received at the beginning; (2) the temperature contrast developed by the foehn; (3) the amount of pressure gradient northward; (4) the direction of air movement in Davis Strait, i. e., whether speeded by southerly or retarded by northerly currents; (5) the energy gained from latent heat; and (6) the effect of the pocketlike configuration of Melville Bay. That only northward movement of these secondaries has been considered may be simply explained by the presence of SE. and SSE. winds in the warm sector, for investigation has shown that in any depression the direction of movement is [7] in the direction of the warm sector current, i. e., approximately parallel to the isobars of the warm sector.

The temperatures and therefore the strength of the foehns resulting from LOWS having very different histories is shown by Table 1. In other words, the LOW of the 8th which moved along a northerly track directly from the plains region of the United States to the Greenland coast is to be compared with the secondary developments which have just been described in some detail.

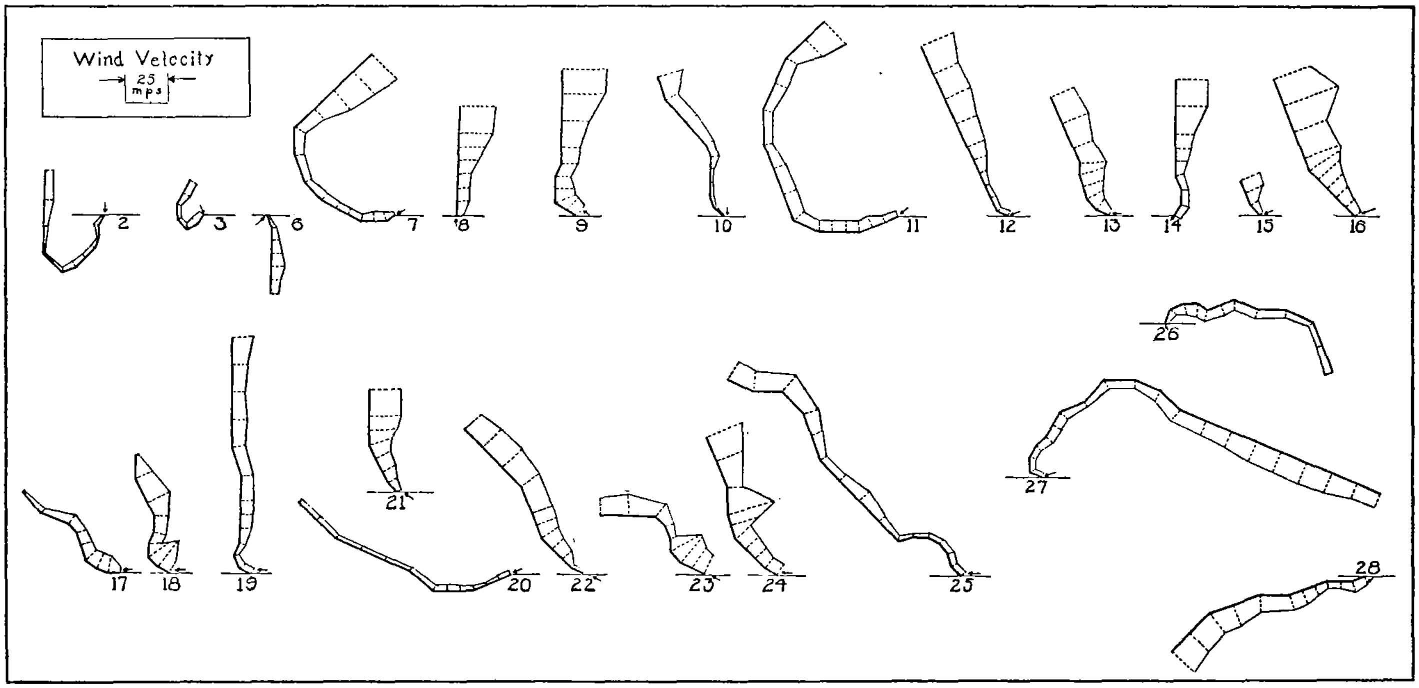

FIGURE 4.—Graphic representation of velocity and direction of upper air at Mount Evans for January 1–28, 1929. The heavy black line is the direction of flight of the pilot balloon. The surface-wind direction is shown by the arrow, and the first six divisions along the heavy black line are for each interval of 250 meters. Above 1,500 meters the intervals are for each 500 meters. The length of the broken line represents the velocity in m. p. s. Sixteen directions are shown, the top of the graph being north, the right east, and so on. Attention is called to the 11th, 25th, and 27th, which exceed 5,000 meters. On the 11th and 25th the last two, and on the 27th the last six intervals are 1,000 meters each.

TABLE 1

	Minimum	Date	Maximum	Date	Range	
					8th	21–25
Upernivik	−1.3	8	31.8	9	33.1	
	15.4	21	49.6	23		34.2
Jacobshavn	.5	8	43.5	8	43.0	
	15.9	21	59.1	23		43.2
Mount Evans	−9.0	7	30.0	8	39.0	
	8.0	20	51.8	24		43.8
Godthaab	10.0	7	37.9	[1] 7	27.9	
	23.0	21	61.3	24		38.3

[1] Maximum for the 8th not available.

The fact which this table should emphasize is, namely, that of the two foehns, the last one produced by a secondary, or secondaries,[8] not only began with higher temperatures, but higher temperatures were maintained throughout a much longer period. Many of the conditions relating to the last foehn have already been given in some detail, so it is only necessary to state here, that of greatest importance in determining the strength of this foehn was the fact that the Labrador depression was extremely deep. Without this, the secondaries would never have begun with such great energy, nor could they have shown so many characteristics peculiar to young cyclones. Concerning the first foehn, it needs only to be stated that its short duration points to a very rapid occlusion. And this rapid occlusion, despite the first foehn's lower pressure at the coast, explains why the first foehn had lower temperatures.

In conclusion it can be said that the origin, development, and course of the LOWS was significant in determining the strength of the Greenland foehns in January, 1929, but further analysis of the foehns and LOWS is desirable in order to determine which of the two types of depressions will cause the greater foehn outbreak.

[7] J. Bjerknes and H. Solberg: Life Cycle of Cyclones and the Polar Front Theory of Atmospheric Circulation. Geof. Pub., Oslo, 1922.

[8] Inasmuch as secondaries the world over develop to the south and southeast of the primary, an alternative view may be entertained, viz, that for the reasons stated by the author there was a redevelopment of energy along the Greenland coast in the original primary cyclone rather than the development of a secondary cyclone.—*Ed.*